

CECW-CE

**DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000**

EM 1110-1-1005

Manual
No. 1110-1-1005

1 January 2007

**Engineering and Design
CONTROL AND TOPOGRAPHIC SURVEYING**

Table of Contents

Subject	Paragraph	Page
Chapter 1 Introduction		
Purpose	1-1	1-1
Applicability	1-2	1-1
Distribution.....	1-3	1-1
References	1-4	1-1
Discussion	1-5	1-1
Use of Manual	1-6	1-2
Scope of Manual.....	1-7	1-2
Life Cycle Project Management Applicability.....	1-8	1-4
Metrics and Accuracy Definitions.....	1-9	1-4
Trade Name Exclusions.....	1-10	1-4
Abbreviations and Terms	1-11	1-4
Mandatory Requirements	1-12	1-4
Governing Engineer Regulations and Related Standards.....	1-13	1-5
Proponency and Waivers.....	1-14	1-5
Chapter 2 Overview of Topographic Surveying Techniques and Methods		
Purpose	2-1	2-1
General Definitions	2-2	2-1
Generic Considerations Applicable to all Drawings and Maps.....	2-3	2-2
SECTION I--Types of Surveys		
Reconnaissance Topographic Surveys	2-4	2-4
Detailed Topographic Surveys	2-5	2-5
Utility Surveys.....	2-6	2-6
As-Built Surveys	2-7	2-8
Reservation Boundary Surveys and Maps.....	2-8	2-9
Reservoir Clearing Surveys.....	2-9	2-11
Upland Disposal Area Surveys.....	2-10	2-12
Channel Improvement and Cutoff Surveys	2-11	2-12
Post-Flood High Water Mark Surveys	2-12	2-12
Route Surveys.....	2-13	2-13

Subject	Paragraph	Page
Bridge Surveys .....	.2-14	2-14
Artillery Surveys (FM 3-34.331).....	2-15	2-15
Airport Obstruction and NAVAID Surveys (FM 3-34.331) .....	.2-16	2-15
Site Plan Engineering Drawings.....	.2-17	2-17
Army Installation Mapping Requirements .....	.2-18	2-18

SECTION II--Survey Methods and Techniques

Older Topographic Surveying Methods .....	.2-19	2-21
Total Stations.....	.2-20	2-23
Real Time Kinematic (RTK) GPS.....	.2-21	2-25
Terrestrial LIDAR (Laser) Scanning .....	.2-22	2-26
Topographic Data Collection Procedures.....	.2-23	2-26
Automated Field Data Collection.....	.2-24	2-28
Methods of Delineating and Densifying Topographic Features.....	.2-25	2-29
General QC and QA Guidance on Topographic Data Collection and Drawings .....	.2-26	2-38

Chapter 3
Primary Control Surveys for Project Mapping

Purpose and Scope.....	3-1	3-1
------------------------	-----	-----

SECTION I--Traditional Horizontal Control Survey Techniques

General Overview.....	3-2	3-2
Secondary or Temporary Horizontal Control.....	3-3	3-7
Bearing and Azimuth Determination.....	3-4	3-8
Electronic Distance Measurement	3-5	3-10
Coordinate Computations	3-6	3-12
Traverse Surveys	3-7	3-14
Traverse Survey Guidelines	3-8	3-16
Traverse Computations and Adjustments.....	3-9	3-17
Traverse Adjustment (Compass Rule).....	3-10	3-19
Triangulation and Trilateration Surveys.....	3-11	3-21

SECTION II--Vertical Control Survey Techniques

General	3-12	3-23
Second-Order Leveling	3-13	3-28
Third-Order and Lower-Order Leveling.....	3-14	3-32
Calibrations and Adjustments.....	3-15	3-37
Care of Level Instruments	3-16	3-39
Routine Maintenance and Care of Level Rods.....	3-17	3-41
Maintenance of Survey Instrument Accessories	3-18	3-42

Chapter 4
Accuracy Standards for Engineering, Construction, and Facility Management Control and Topographic Surveys

Purpose	4-1	4-1
General Surveying and Mapping Specifications	4-2	4-1
Accuracy Standards for Engineering and Construction Surveying	4-3	4-2

Subject	Paragraph	Page
Accuracy Standards for Maps and Related Geospatial Products.....	4-4	4-5
Photogrammetric Mapping Standards and Specifications.....	4-5	4-10
Cadastral or Real Property Survey Accuracy Standards	4-6	4-10
Hydrographic Surveying Accuracy Standards	4-7	4-13
Structural Deformation Survey Standards	4-8	4-13
Geodetic Control Survey Standards	4-9	4-13
State and Local Accuracy Standards	4-10	4-15
CADD/GIS Technology Center Standards.....	4-11	4-19
Mandatory Standards.....	4-12	4-19

Chapter 5

Geodetic Reference Datums and Local Coordinate Systems

Purpose and Background.....	5-1	5-1
SECTION I--Geodetic Reference Systems		
General	5-2	5-2
Geodetic Coordinates	5-3	5-2
Datums.....	5-4	5-4
WGS 84 Reference Ellipsoid.....	5-5	5-5
Horizontal Datums and Reference Frames.....	5-6	5-6
SECTION II--Horizontal Coordinate Systems		
General	5-7	5-10
Geographic Coordinates	5-8	5-10
State Plane Coordinate Systems	5-9	5-10
Grid Elevations, Scale Factors, and Convergence.....	5-10	5-14
Universal Transverse Mercator Coordinate System	5-11	5-15
The US Military Grid-Reference System (FM 3-34.331)	5-12	5-15
US National Grid System	5-13	5-16
Chainage-Offset Coordinate Systems	5-14	5-17
Datum Conversions and Transformation Methods.....	5-15	5-19
Horizontal Transition Plan from NAD 27 to NAD 83	5-16	5-22
SECTION III--Vertical Reference Systems		
National Geodetic Vertical Datum of 1929 (NGVD 29).....	5-17	5-25
North American Vertical Datum of 1988 (NAVD 88).....	5-18	5-25
Other Vertical Reference Datums and Planes	5-19	5-26
Orthometric Elevations.....	5-20	5-27
WGS 84 Ellipsoidal Heights	5-21	5-28
Orthometric Height and WGS 84 Ellipsoidal Elevation Relationship	5-22	5-29
Geoid Undulations and Geoid Models	5-23	5-30
Using GPS to Densify Orthometric Elevations	5-24	5-30
Vertical Datum Transformations.....	5-25	5-31
Vertical Transition Plan from NGVD 29 to NAVD 88.....	5-26	5-32
Vertical Control in Areas Subjected to Subsidence or Sea Level Rise	5-27	5-33
Mandatory Standards.....	5-28	5-35

Subject	Paragraph	Page
Chapter 6		
Planning and Conducting Control and Topographic Surveys		
Purpose	6-1	6-1
Project Requirements from Using Agency	6-2	6-1
Topographic Survey Planning Checklist	6-3	6-4
Rights-of-Entry.....	6-4	6-7
Sources of Existing Geospatial/Survey Data.....	6-5	6-8
Project Control for Topographic Detail Surveys.....	6-6	6-9
Establishing NSRS Control at a Project Site	6-7	6-12
Project Control Densification Methods	6-8	6-12
Extending Control from a Local Project or Installation Network (Patrick AFB)....	6-9	6-13
Extending Control from a Distant Network Using		
Continuously Operating Reference Stations (CORS).....	6-10	6-15
On-Line Positioning User Service (OPUS)	6-11	6-21
Establishing Approximate Control for an Isolated		
or OCONUS Construction Project	6-12	6-21
Determining Required Map Scale and Contour Interval	6-13	6-22
Recommended Guidelines for Army Installation Maps and Drawings	6-14	6-30
Topographic Survey Equipment Selection and Planning Guidance.....	6-15	6-37
Chapter 7		
Field Data Collectors and Coordinate Geometry Functions		
Purpose	7-1	7-1
Field Survey Notes--Manual and Electronic	7-2	7-1
Functional Requirements of a Generic Data Collector.....	7-3	7-4
General Software Features on a Data Collector	7-4	7-5
Feature or Descriptor Codes for Topographic Field Data	7-5	7-6
Descriptor Codes and Level Assignments for Various Topographic Features.....	7-6	7-10
Feature and Attribute Libraries for Topographic Field Data.....	7-7	7-18
Control Commands for Connecting Feature Line Strings	7-8	7-20
Field Coordinate Geometry Options	7-9	7-21
General COGO Computation Routines	7-10	7-22
Total Station Resection Computations	7-11	7-24
Line-Line Intersection Computations.....	7-12	7-26
Chapter 8		
Total Station Topographic Survey Procedures		
Purpose	8-1	8-1
Total Stations.....	8-2	8-1
Total Station Features and Operation	8-3	8-3
Reflectorless and Robotic Total Stations.....	8-4	8-5
Field Equipment Inventory and Maintenance	8-5	8-6

Subject	Paragraph	Page
Total Station Job Planning.....	8-6	8-8
Total Station Error Sources	8-7	8-9
General Total Station Operating Procedures	8-8	8-12
Total Station Angle Measurement and Traverse Techniques.....	8-9	8-14
Total Station Leveling Field Procedures	8-10	8-14
Positioning Topographic Features with a Total Station	8-11	8-17

Chapter 9

GPS Real Time Kinematic Topographic Survey Procedures

Purpose and Scope.....	9-1	9-1
RTK Field Techniques	9-2	9-2
Standard RTK Observing Procedures	9-3	9-5
Site Calibration.....	9-4	9-7
RTK Survey Field Data Collection Procedures and Checks	9-5	9-10
Guidance for Setting Construction Control Points Using RTK Techniques	9-6	9-12

Chapter 10

Terrestrial 3D Laser Scanners

Purpose	10-1	10-1
Background	10-2	10-1
Scanner Operation and Data Processing.....	10-3	10-4
Corps of Engineers Project Application:		
St. Lucie Lock and Dam, Jacksonville District	10-4	10-6
Corps of Engineers Project Application:		
Portuguese Dam Foundation Construction, Ponce, PR, Jacksonville District ...	10-5	10-8
Corps of Engineers Application:		
Steel Bayou Levee Surveys, Vicksburg District	10-6	10-10
Corps of Engineers Application:		
Structure Subsidence Survey, Philadelphia District.....	10-7	10-12

Chapter 11

Final Site Plan or Map Production

Purpose	11-1	11-1
Overview of Topographic Survey Data Flow.....	11-2	11-1
Basic Definitions of Geospatial Data used in CADD or GIS Databases.....	11-3	11-3
SDSFIE Data Model.....	11-4	11-7
Data Collection and Processing Procedures for Topographic Surveys	11-5	11-8
Field Computers and Software for Viewing and Processing Data	11-6	11-9
Field Quality Control and Quality Assurance Checks.....	11-7	11-11
Cell Libraries Containing Corps of Engineers Standardized Symbology	11-8	11-13
Sheet and Model Files	11-9	11-14
Reference Files	11-10	11-14
Level Assignments for Surveying and Mapping	11-11	11-15

Subject	Paragraph	Page
Chapter 12		
Survey Documentation and Submittals		
General	12-1	12-1
Final Survey Report Format--Civil Works	12-2	12-1
Final Survey Report Format--Military	12-3	12-2
Field Note Keeping Procedures and Formats	12-4	12-3
Sample Topographic Survey Field Book Notes	12-5	12-6
Monument Descriptions	12-6	12-10
Standardized Coordinate File Coding (New Orleans District)	12-7	12-11
Creating Metadata for Topographic Surveys.....	12-8	12-16
Sample Submittal of Feature Data Accuracy	12-9	12-21
Deliverable QA Checklist.....	12-10	12-22
Mandatory Criteria	12-11	12-22
Chapter 13		
Topographic Survey Contracting and Cost Estimating		
General Contracting Policies and Procedures	13-1	13-1
Indefinite Delivery Contracts	13-2	13-3
Cost Estimates for Contracted Topographic Mapping IDCs.....	13-3	13-6
Task Order Time and Cost Estimates	13-4	13-9
Task Order Request for Proposal	13-5	13-11
Government Cost Estimate for a Task Order	13-6	13-15
AE Services Request for Task Order Issuance	13-7	13-17
Labor Hour Task Orders for Construction Surveying Services.....	13-8	13-18
Hired-Labor Survey Cost Estimates	13-9	13-20

Subject	Paragraph/ Page
Appendix A References	A-1
Appendix B Requirements and Procedures for Referencing Coastal Navigation Projects to Mean Lower Low Water (MLLW) Datum	B-1
Appendix C Development and Implementation of NAVD 88	C-1
Appendix D Sample Scopes of Work and Guide Specifications for Topographic Surveying Services	D-1
Appendix E Application: Topographic Survey of Beach Sections Adjacent to Tillamook North Jetty, Oregon (Portland District)	E-1
Appendix F Application: Topographic Survey for Relocation of Red Feather Prairie Bike Trail, Saylorville Lake Project, Iowa (Rock Island District)	F-1
Appendix G Application: Topographic Survey of Hannibal Lock & Dam, Proposed Nationwide DGPS Antenna Site (Pittsburgh District)	G-1
Appendix H Application: Topographic and Planimetric Survey--Proposed Military Fitness Center (Tulsa District)	H-1
Appendix I Application: Control and Topographic Surveys Vicinity Footbridge at Willamette Mission Bottom, Oregon (Portland District)	I-1
Appendix J Application: Topographic Survey for Proposed US Army Reserve Center Belaire, Belmont County, Ohio (Louisville District)	J-1
Appendix K Application: Topographic and Boundary Surveys, Bayou Baton Rouge Drop Structure, Amite River and Tributaries, Comite River Diversion Project, East Baton Rouge Parish, Louisiana (New Orleans District)	K-1
Appendix L Glossary	L-1